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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 663

THE EFFECTS OF PARTIAL-SPAN PLAIN FLAPS
ON THE AERODYNAMIC CHARACTERISTICS OF A RECTANGULAR
AND A TAPERED CLARK Y-WING

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SUMMARY

An investigation was made in the N.A.C.A. 7- by 10-foot wind tunnel to determine the aerodynamic characteristics of tapered and rectangular wings with partial-span plain flaps. Two Clark Y airfoils equipped with center-section and with tip-section flaps were tested.

The results showed that the aerodynamic characteristics of partial-span plain flaps were, in general, similar to those of split flaps of the same span, but that the lift and the drag were less for the wing with plain flaps than for the wing with split flaps of comparable size. For the rectangular wing with center-section plain flaps, the maximum lift and the lift-drag ratio at maximum lift were greater and the drag at maximum lift was less than for the wing with tip-section plain flaps of the same size. The maximum lift of the tapered wing varied in the same manner as that of the rectangular wing but the drag and the lift-drag-ratio relationships were opposite.

INTRODUCTION

Many arrangements of wing flaps have been tested in wind tunnels and in flight. Partial-span flaps are employed in nearly all cases so that part of the trailing edge can be used for lateral control, and frequently a section must be cut out at the center to allow for the fuselage.

Wind-tunnel tests of partial-span split flaps on rectangular and tapered wings have been reported in references 1 and 2. The present investigation deals with similar arrangements of plain flaps.

APPARATUS AND TESTS

Models.— The models used in these tests are Clark Y wings of laminated mahogany, each model having a span of 60 inches and an aspect ratio of 6. One airfoil is rectangular in plan form (fig. 1) and the other is tapered 5:1 (fig. 2). For the tapered wing, the Clark Y profile was used at all sections along the span and the maximum ordinates of all sections were in a horizontal plane on the upper surface.

The chord of the flaps is 20 percent of the wing chord at any longitudinal section for both wings. The flaps were deflected about the axes shown, the angles being measured in a plane normal to the axis of deflection. The gaps between flap and wing were sealed for all tests. The flaps were cut into sections to form ten flaps of equal span.

Wind tunnel.— The models were mounted on the standard force-test tripod in the N.A.C.A. 7-by 10-foot closed-throat wind tunnel, which is described in detail in reference 3.

Tests.— The tests were made at a dynamic pressure of 16.37 pounds per square foot, corresponding to an air speed of about 80 miles per hour at standard sea-level conditions.

Tests were made with center-section and tip-section flaps 20, 40, 60, and 80 percent of the span deflected 60° and with full-span flaps neutral and deflected 60° . The angles of attack covered a range from approximately -14° to 20° , which included zero and maximum lifts.

RESULTS AND DISCUSSION

Coefficients

The results are given in the form of absolute coefficients of lift, drag, and pitching moment.

$$C_L = \frac{L}{qS}$$

$$C_D = \frac{D}{qS}$$

$$C_{m(a.c.)_0} = \frac{M}{qcS}$$

where

L is wing lift.

D, wing drag.

M, pitching moment about aerodynamic center of plain wing.

q, dynamic pressure.

S, wing area.

c, mean wing chord.

The data have been corrected for the effects of the wind-tunnel jet boundaries to aspect ratio 6 in free air.

Rectangular Wing

Curves of lift, drag, and center-of-pressure location for the rectangular wing with center-section flaps are given in figure 3 and curves of pitching moment in figure 4. Similar curves for the rectangular wing with tip-section flaps are given in figures 5 and 6. No unusual characteristics are shown, the values of C_L , C_D , and $C_{m(a.c.)_0}$

increasing with increase in flap span. The peaks of the lift curves are sharper and the stall occurs at a lower angle of attack for the wings with both the center-section and the tip-section plain flaps than for the plain wing.

The values of $C_{L_{max}}$ and of C_D at $C_{L_{max}}$ increase as the flap span is increased for the wing equipped with either the center- or the tip-section plain flap (fig. 7). The wing with the center-section flap has a higher value of $C_{L_{max}}$ and a lower value of C_D at $C_{L_{max}}$ than the

wing with tip-section flaps of equal span.

The values of L/D at $C_{L_{max}}$ decrease with increase of flap span except for the wing with a center-section flap of span less than $0.20b$. Lower values of L/D are obtained with the tip-section flaps than with the center-section flap.

The foregoing discussion indicates that, for landing, the advantage of the higher maximum lift obtained with the center-section flap might be somewhat offset by the lower drag, and that a slower but flatter landing would be attained with the center-section flap.

The curves of lift, drag, and center-of-pressure location for the wings with partial-span plain flaps show the same general characteristics as those for a wing with partial-span split flaps (reference 1). The maximum lift and the drag at maximum lift for the wing with the plain flaps are less and the stall occurs at a somewhat lower angle of attack than for the wing with split flaps of the same size. (The data of reference 1 were corrected to aspect ratio 6 in free air for these comparisons.)

The difference in maximum lift for the wings with the center-section flap or with tip-section flaps of equal span is less for plain flaps than for split flaps. It should also be noted that, whereas the drag is the same for the wings fitted with either tip-section split flaps or the center-section split flap, the wing with tip-section plain flaps has higher drag than the one with the center-section flap.

Tapered Wing

Plots of lift, drag, and center-of-pressure location for the 5:1 tapered wing with a center-section plain flap are given in figure 8, and pitching moments are plotted in figure 9. Plots of the same coefficients for the tapered wing with tip-section flaps are given in figures 10 and 11. It will be noticed that the values of lift, drag, and pitching-moment coefficients increase as the flap span is increased, the magnitude of the increments being greater for the inboard sections than the outboard owing to difference in flapped area. The peaks of the lift curves are not so sharp as those for the rectangular wing with partial-span plain flaps, and the angle of attack for maximum lift decreases as the flap span is increased.

With the exception of the O.20b tip-section flap, $C_{L_{max}}$ and C_D at $C_{L_{max}}$ increase and L/D at $C_{L_{max}}$ decreases with increase in flap span (fig. 12). Because of the difference in flapped area, center-section flaps have the highest $C_{L_{max}}$ and C_D at $C_{L_{max}}$ and the lowest L/D at $C_{L_{max}}$, so that airplanes so equipped make the slowest and steepest landings.

The lift and the drag of a tapered wing with partial-span flaps are less for plain than for split flaps and maximum lift occurs at a lower angle of attack, as was the case for the rectangular wing (reference 2). The center of pressure of the tapered wing is farther forward when split flaps are used; the reverse was true for the rectangular wing.

CONCLUSIONS

1. The changes in lift and drag with flap span for both rectangular and tapered wings having partial-span plain flaps were similar to those for corresponding wings with partial-span split flaps.

2. The maximum lift and the drag at maximum lift of a rectangular and of a tapered Clark Y wing having partial-span flaps were less for the wing with plain flaps than for the wing with split flaps.

3. The maximum lift and the lift-drag ratio at maximum lift of a rectangular Clark Y wing with partial-span plain flaps were greater and the drag at maximum lift was less with a center-section flap than with tip-section flaps of equal span.

4. The tapered Clark Y wing had a higher value of maximum lift and of drag at maximum lift and a lower value of lift-drag ratio at maximum lift when equipped with a center-section plain flap than with tip-section flaps of equal span.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 15, 1938.

REFERENCES

1. Wenzinger, Carl J.: The Effect of Partial-Span Split Flaps on the Aerodynamic Characteristics of a Clark Y Wing. T.N. No. 472, N.A.C.A., 1933.
2. Wenzinger, Carl J.: The Effects of Full-Span and Partial-Span Split Flaps on the Aerodynamic Characteristics of a Tapered Wing. T.N. No. 505, N.A.C.A., 1934.
3. Wenzinger, Carl J., and Harris, Thomas A.: Tests of an N.A.C.A. 23012 Airfoil with Various Arrangements of Slotted Flaps in the Closed-Throat 7- by 10-Foot Wind Tunnel. T.R. No. (to be published), N.A.C.A., 1938.

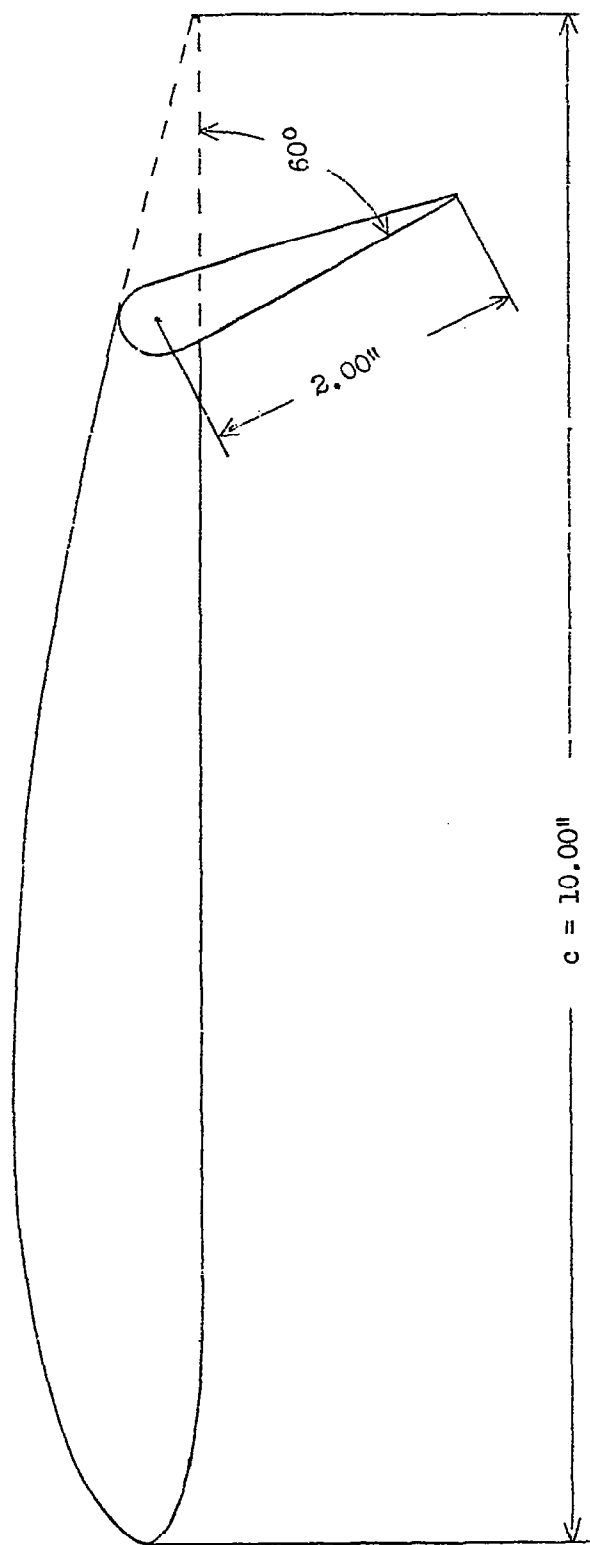


Figure 1.- Plain flap on the rectangular Clark Y wing.

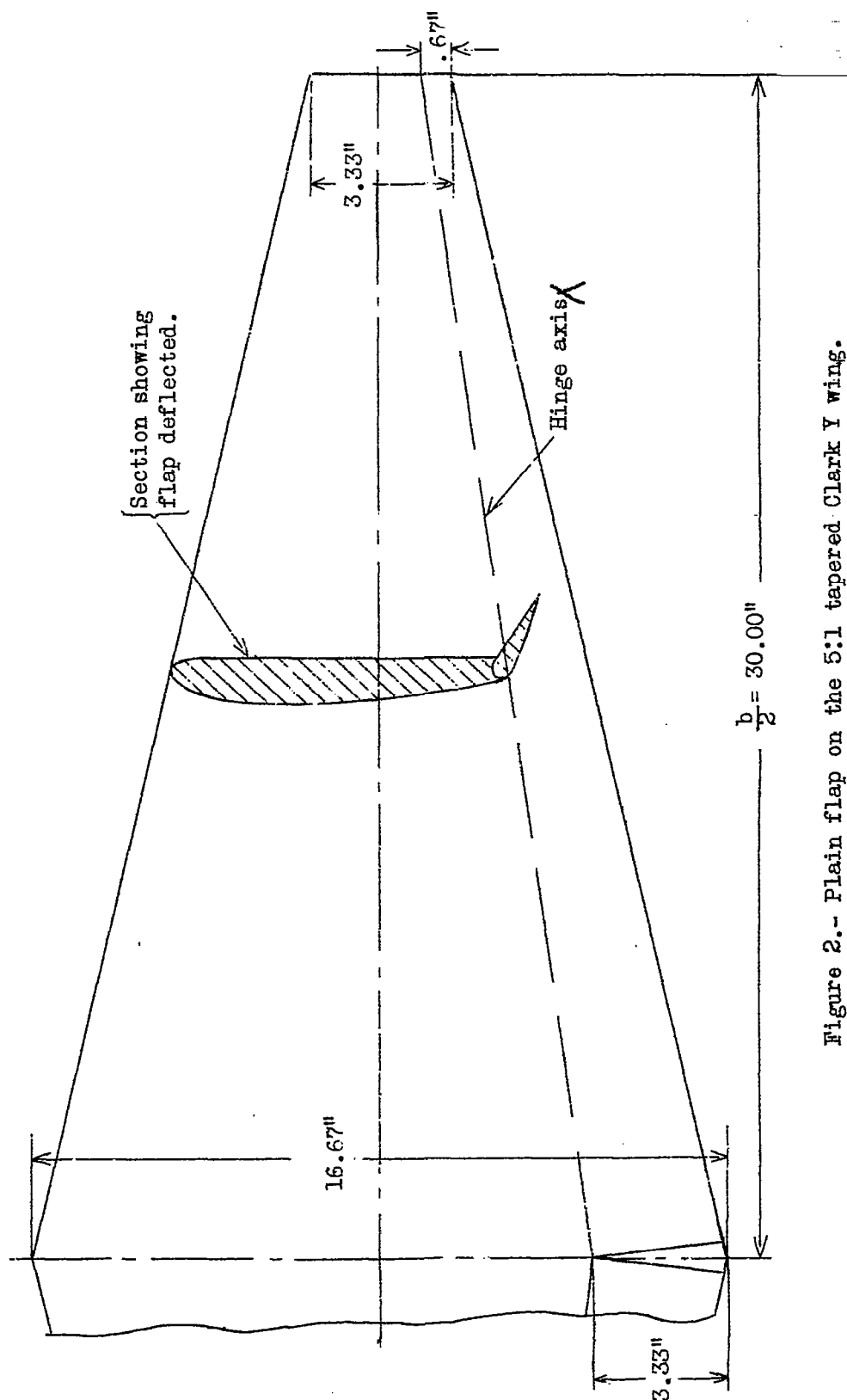
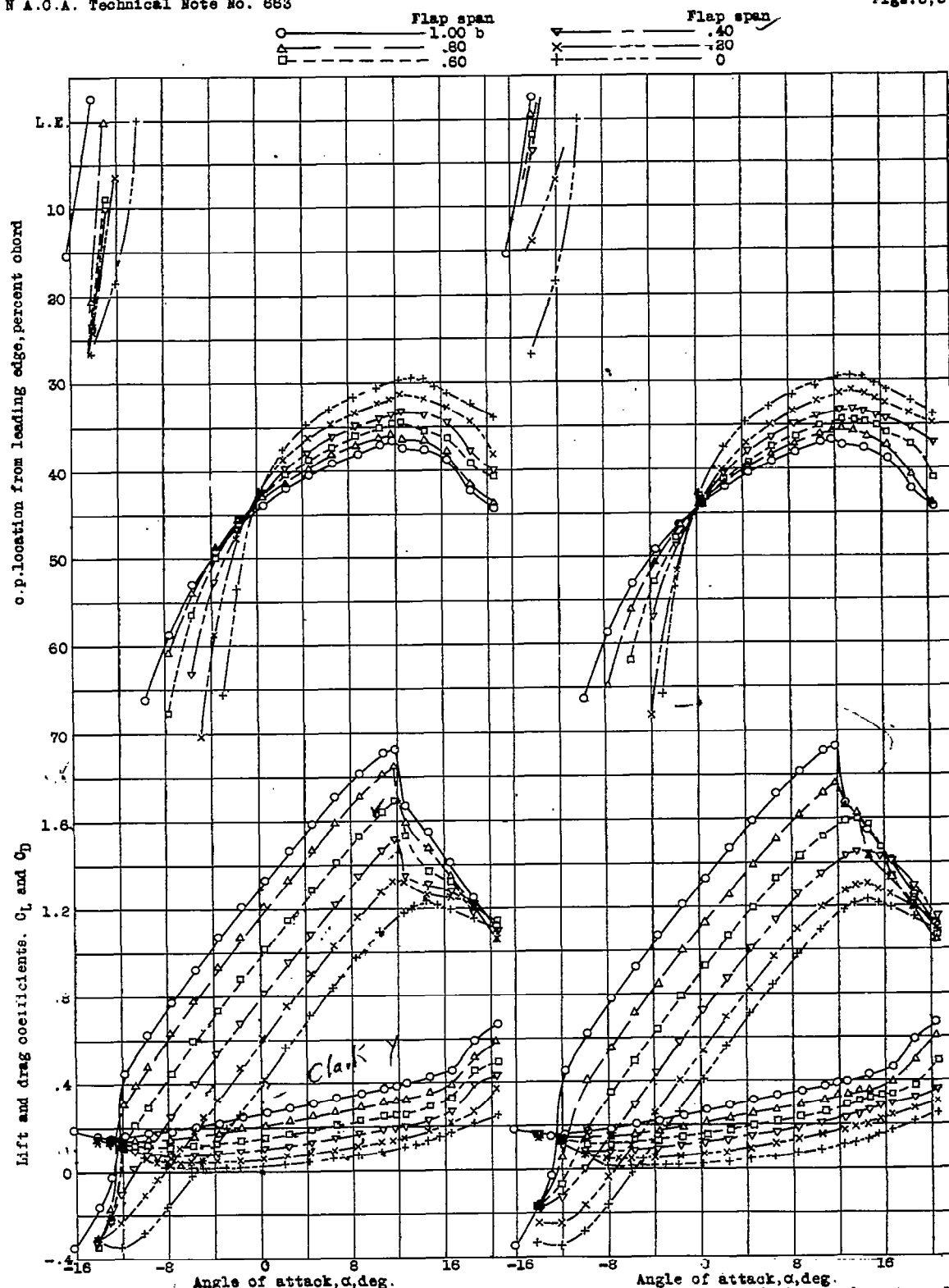


Figure 2.- Plain flap on the 5:1 tapered Clark Y wing.



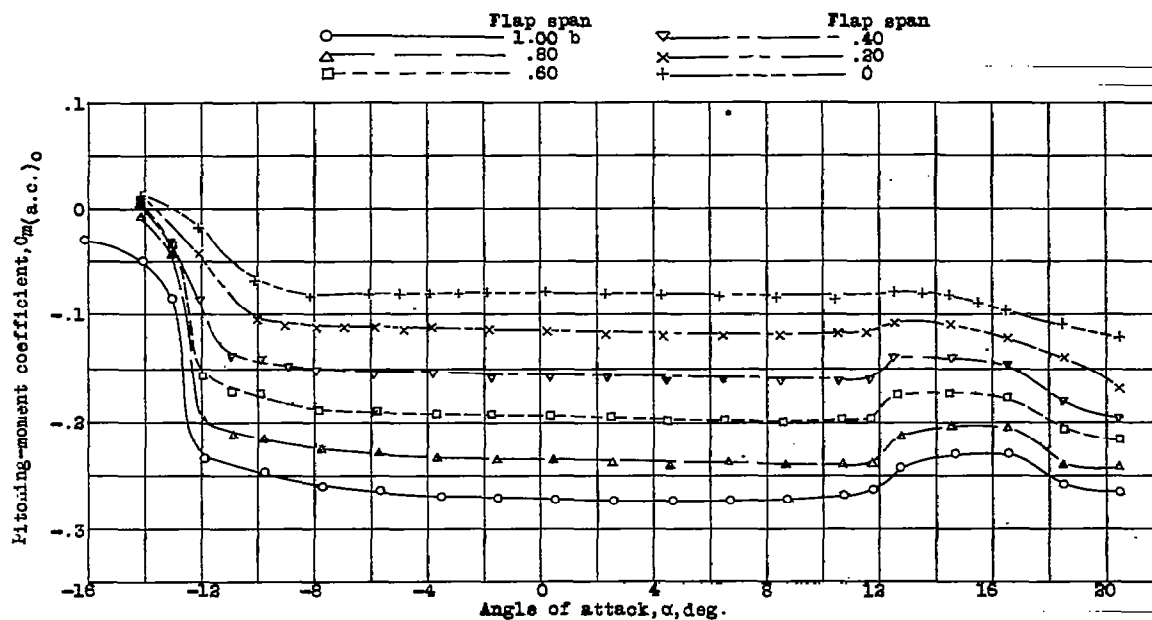


Figure 4.- Variation of pitching-moment coefficient with angle of attack. Center-section plain flap on the rectangular Clark Y wing $\delta_f = 60^\circ$.

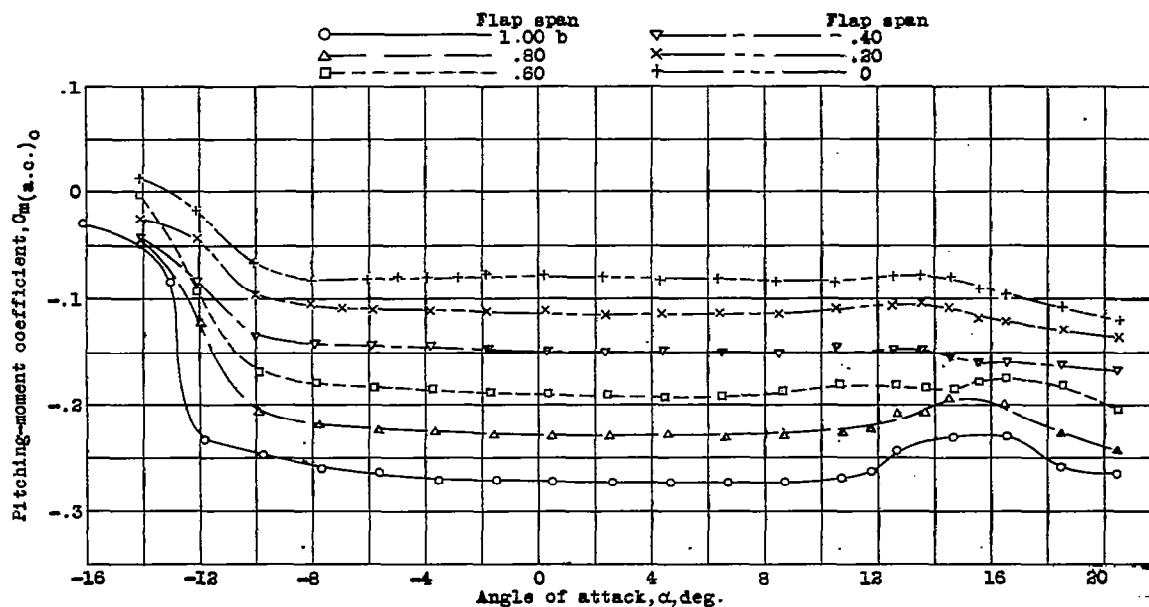


Figure 6.- Variation of pitching-moment coefficient with angle of attack. Tip-section plain flaps on the rectangular Clark Y wing. $\delta_f = 60^\circ$.

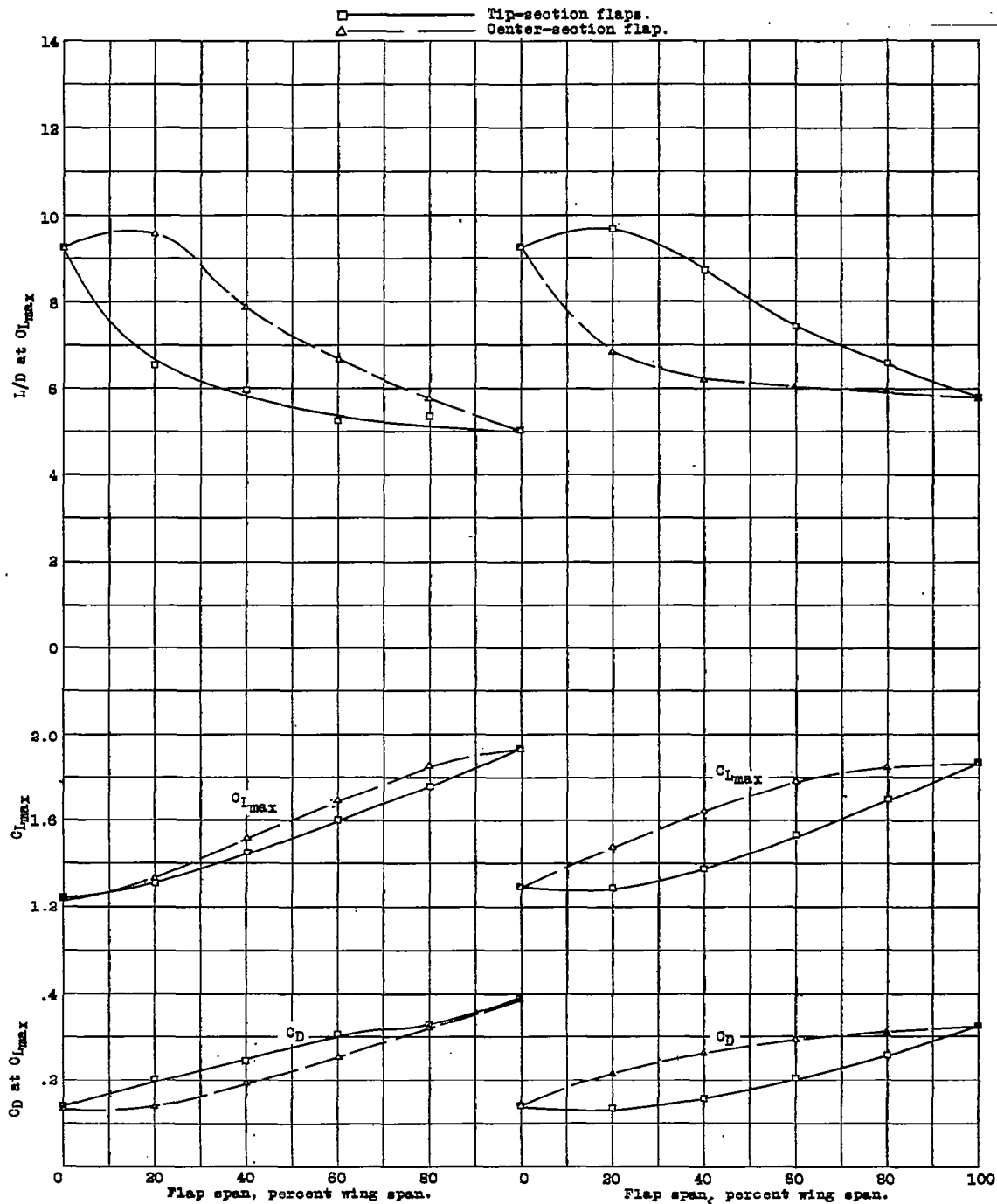


Figure 7 - Effect of flap length on $C_{l_{max}}$, on C_d at $C_{l_{max}}$, and on L/D at $C_{l_{max}}$. Rectangular Clark Y wing. $\delta_f = 60^\circ$.

Figure 12.- Effect of flap length on $C_{l_{max}}$, on C_d at $C_{l_{max}}$, and on L/D at $C_{l_{max}}$. Tapered Clark Y wing. $\delta_f = 60^\circ$.

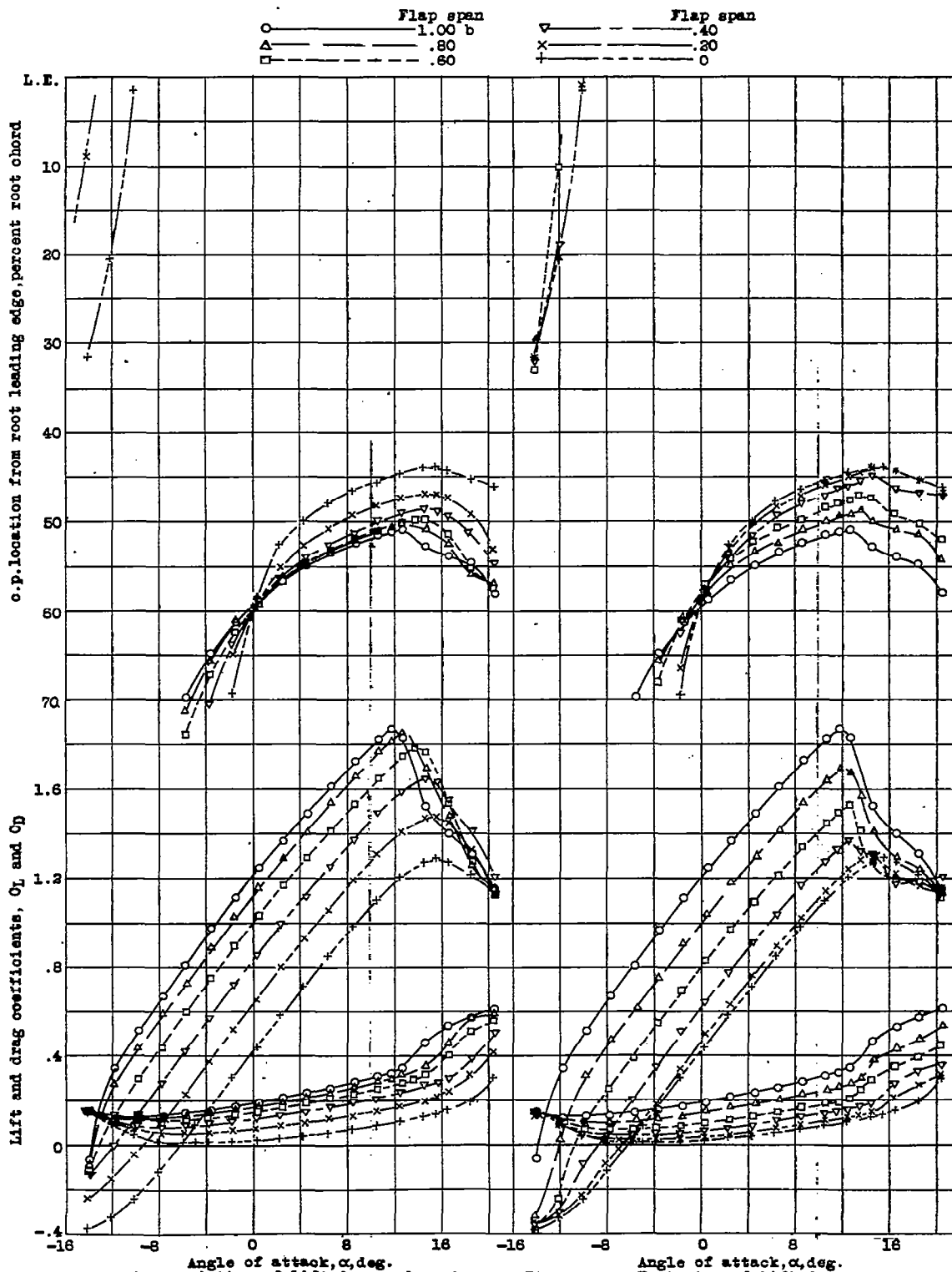


Figure 8.- Variation of lift, drag, and center of pressure with angle of attack. Center-section plain flap on the tapered Clark Y wing. $\delta_r = 60^\circ$.

Figure 10.- Variation of lift, drag, and center of pressure with angle of attack. Tip section plain flaps on the tapered Clark Y wing. $\delta_r = 60^\circ$.

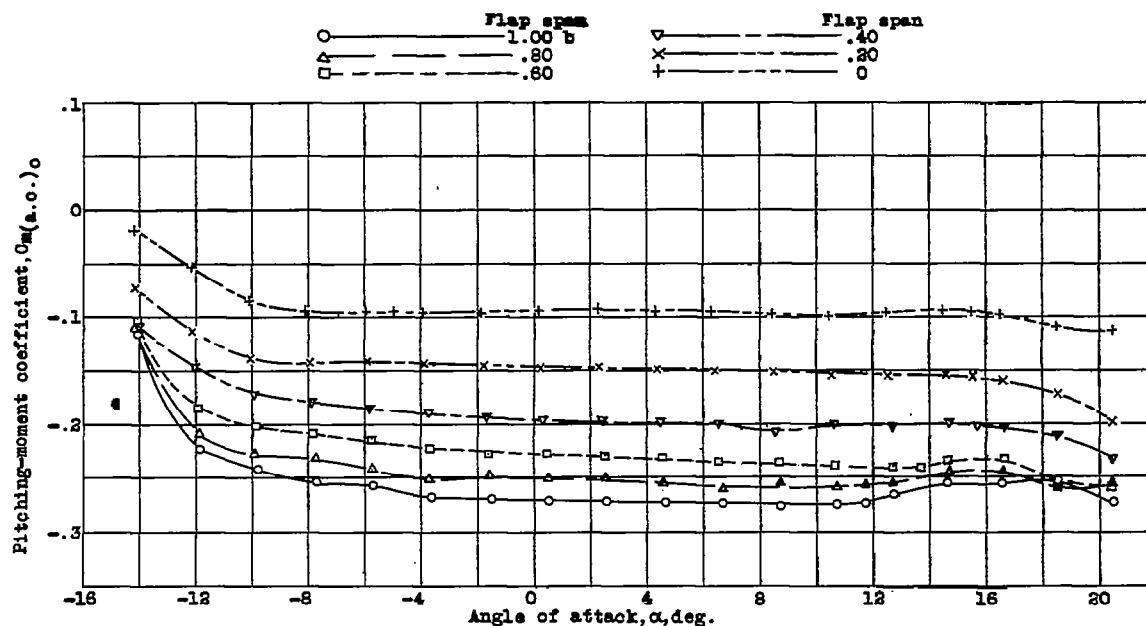


Figure 9.- Variation of pitching-moment coefficient with angle of attack. Center-section plain flaps on the tapered Clark Y wing. $\delta_f = 60^\circ$.

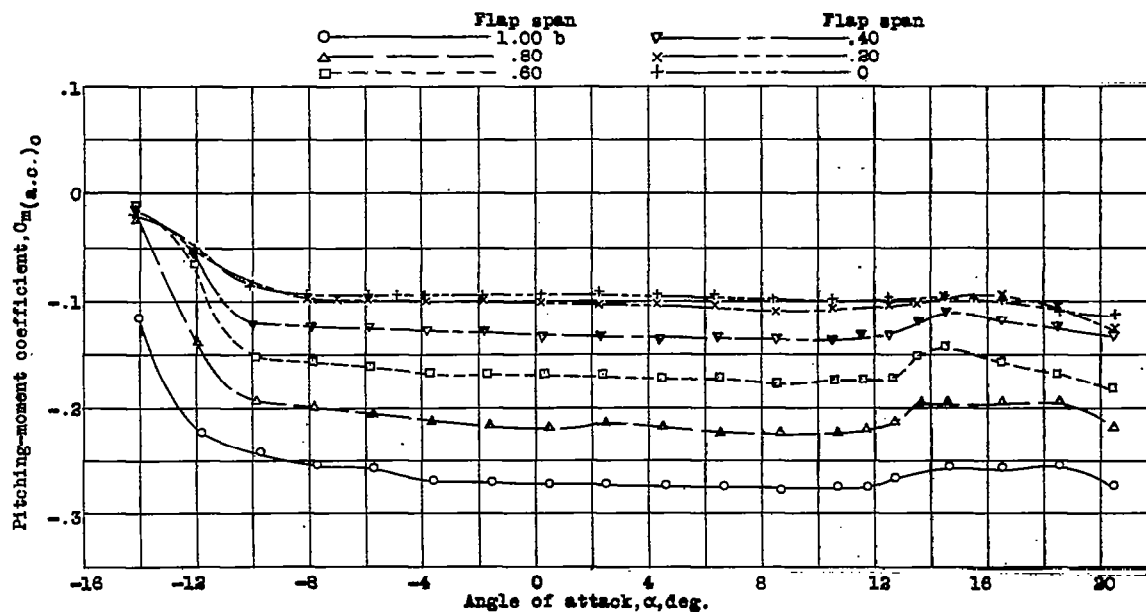


Figure 11.- Variation of pitching-moment coefficient with angle of attack. Tip-section plain flaps on the tapered Clark Y wing. $\delta_f = 60^\circ$.